Correlated Neutron Emission in Fission

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We have developed a new and powerful tool to study the process of sequential neutron emission from fission fragments (FF). We have implemented a Monte Carlo simulation of this decay process that allows us to infer important physical quantities that could not be assessed otherwise, for instance, within the original Los Alamos model framework. In particular, the multiplicity distribution of prompt neutrons P(ν), the distribution of ν as a function of the FF mass number, and neutron-neutron correlations can all be inferred from the present work.

This research is motivated in part by the needs of detecting correlated neutrons from a fission chain, for active and passive detection of special nuclear materials for nonproliferation applications.

Within this approach, we calculate both the center-of-mass and laboratory frame prompt neutron energy spectra, the prompt neutron multiplicity distribution P(ν), and the average total number of emitted neutrons as a function of the mass of the fission fragment $\bar{\nu}$ (A). Two assumptions for partitioning the total available excitation energy among the light and heavy fragments are considered. One assumption is that the temperatures in the light and heavy fragments are equal (an hypothesis identical to the one made in the Los Alamos model [1]) at the instant of scission. In the alternative hypothesis, the experimental $\bar{\nu}$ (A) is used to infer the initial excitation of each fragment. Preliminary results for the neutron-induced fission of ^{235}U (at 0.53 MeV neutron energy) and for the spontaneous fission of ^{252}Cf have been obtained.

For the neutron-induced reaction on ^{235}U, the neutron energy spectrum in the laboratory frame is shown in Fig. 1, as calculated using the two different hypotheses for distributing the total available excitation energy among the FF. Also shown for comparison are the experimental data points by Johansson and Holmqvist [2]. The spectrum obtained by assuming equal nuclear temperatures in both FF at scission is shown to be too soft when compared with experimental data, while the spectrum obtained by splitting the energy according to $\bar{\nu}_{exp}$(A) is too hard.

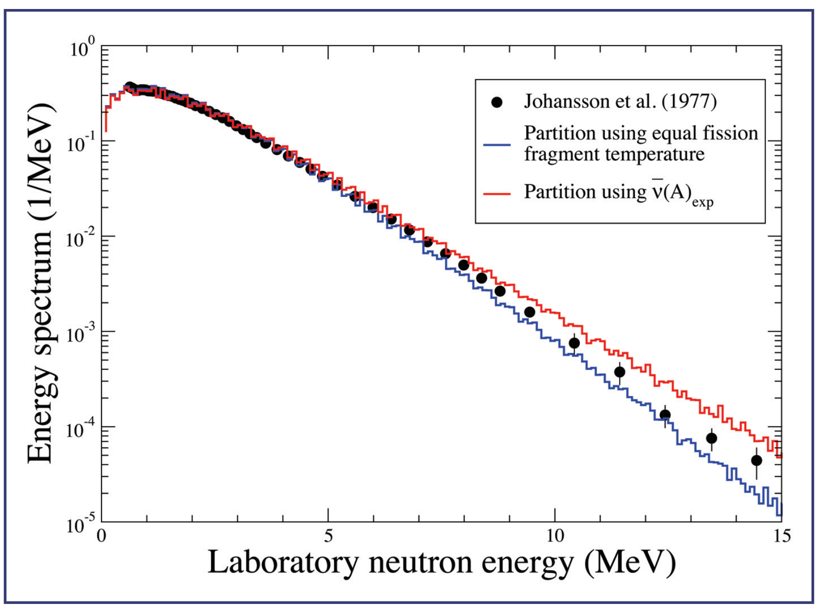

Figure 1— ***Neutron energy spectrum for n(0.53 MeV) + ^{235}U reaction. The red line is the Monte Carlo calculation result assuming partitioning of the FF total excitation energy as a function of $\bar{\nu}$ (A) and the blue line is the result obtained under the assumption of an equal temperature of complementary FF. The experimental points are from Johansson and Holmqvist [2].***

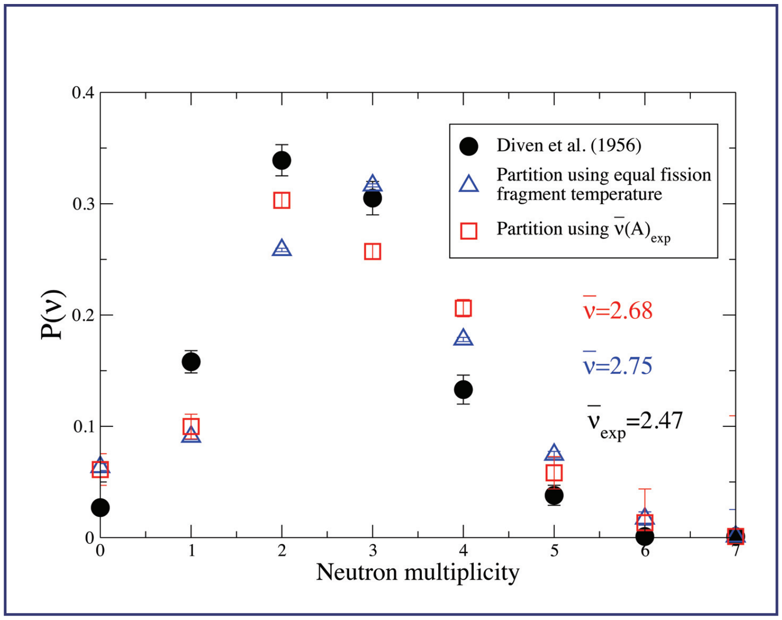

Figure 2— ***Neutron multiplicity distribution for n(0.53 MeV) + ^{235}U reaction. Open square symbols □ are from our Monte Carlo calculation assuming partitioning of FF total excitation energy as a function of $\bar{\nu}$ (A), triangles Δ are the result obtained under the assumption of an equal temperature of complementary FF. The full points are experimental data from Diven et al. [3].***

The calculated neutron multiplicity distribution P(ν) is compared to the experimental distribution by Diven et al. [3] in Fig. 2. In both calculated cases, the average $\bar{\nu}$ of the distribution is larger than the experimental value ($\bar{\nu}_{exp}$ = 2.47, Diven et al. [3]). We found $\bar{\nu}$ = 2.75 in the case of equal nuclear temperature for both FF and $\bar{\nu}$ = 2.68 in the other case. In the case of ^{252}Cf spontaneous fission, similar qualitative conclusions can be drawn. More details can be found in [4].

[1] D.G. Madland and J.R. Nix, *Nucl. Sci. Eng.* **81**, 213 (1982).

[2] P.I. Johansson and B. Holmqvist, *Nucl. Sci. Eng.* **62**, 695 (1977).

[3] B.C. Diven, et al., *Phys. Rev.* **101**, 1012 (1956).

[4] S. Lemaire, et al., in *Proceedings of International Conference on Nuclear Data for Science & Technology, ND2004, Santa Fe, Sept. 26-Oct. 1, 2004* (AIP, Melville, NY, 2005), in press.

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